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Estimation of radionuclides concentration and average annual committed effective dose due to ingestion for some selected medicinal plants of South India

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ABSTRACT

Eight medicinal plants and soil samples from the Malnad area of Karnataka in South India (N 13°29′35.4″; E 75°18′02.4″) were analysed for activity concentrations of natural and artificial radionuclides using HPGe gamma spectrometry. The average annual committed effective dose (AACED) due to the ingestion of radionuclides from medicinal plants were also estimated. The activity concentrations of ^{226}Ra, ^{210}Pb, ^{232}Th, and ^{40}K were found to vary in the range of 32.27–60.12 Bqkg^{-1}, 56.09–160.56 Bqkg^{-1}, 49.61–98.46 Bqkg^{-1}, and 241.57–712.85 Bqkg^{-1}, respectively, in the soil samples and 2.66–11.27 Bqkg^{-1}, BDL to 87.03 Bqkg^{-1}, 2.42–8.72 Bqkg^{-1}, and 93.79–6831.40 Bqkg^{-1}, respectively, in the medicinal plants corresponding to the soil samples. The activity concentration of artificially produced radionuclide ^{137}Cs was BDL to 12.34 Bqkg^{-1} in the soil and it was below detectable level (BDL) in all the plant samples. The soil to plant transfer factors (TF) varied from 0.07 to 0.27, BDL to 0.80, 0.04 to 0.13 and 0.17 to 23.80, respectively, for ^{226}Ra, ^{210}Pb, ^{232}Th, and ^{40}K. The AACED due to the ingestion of radionuclides from the medicinal plants varied from 0.0075 to 0.1067 mSvy^{-1}. The AACED values reported in this study are much below the world average value of 0.30 mSvy^{-1} for an individual. This indicates that there is no radiological health risk in using these plants for medicinal purposes. This study may also contribute data on local medicinal plants to formulate regulations related to radiological healthcare.

1. Introduction

The use of medicinal plants for treating diseases is probably the oldest existing method that humanity has used to cope with illnesses. Medicinal plants have been used therapeutically all around the world and is an important aspect of various traditional medicine systems. From Ayurveda to the Chinese traditional medicine, from Unani to Tibetan medicine, from Amazonian to African medicine, all systems,

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although based on different theoretical and cultural models, integrate phytotherapy into their doctrine (WHO, 2007). Medicinal systems such as Ayurveda, Yoga, Unani, Siddha, and other traditional systems are in regular practice all over India, and more so in rural areas. All these systems use plants and different parts of the plants as the main ingredients of the medicine.

It is well-known that there are many contaminants and residues that may harm the consumers of herbal medicines, and naturally occurring radionuclides are one type of contaminants amongst them (WHO, 2007). In most places on earth, natural radioactivity varies only within relatively narrow limits, whereas in some other localities significant deviations have been observed. All these radionuclides present in the environment are taken up by the plants through the metabolic process and are present in varied concentrations in different parts of the plants (Golmakani, Moghaddam, & Hosseini, 2008; Harb, E-Kamel, E-Mageed, Abbady, & Rashed, 2014; Karunakara, 1997; Kannan, Rajan, Iyengar, & Ramesh, 2002; Lordford, Emmanuel, Cyril, & Alfred, 2013; Patra, Jaison, Baburajan, & Hegde, 2008).

Moreover, the plants absorb many elements present in the soil of their root area with or without the necessity of these elements. Sometimes, the uptake of some non-essential radioactive elements to the plants may occur along with chemically similar essential elements required for the plant metabolism (Manigandan & Chandrashekar, 2014). The transport of these radionuclides also depends on the chemical form of the nuclide, its distribution coefficient, the metabolic requirements of the plant, and physicochemical parameters of the soil such as pH, organic matter, moisture content, etc. (Eisenbud, 1987; IAEA, 2006; Lordford et al., 2013). The presences of radionuclides such as ^{226}Ra, ^{210}Po, ^{210}Pb, etc., in the soil are metabolically incorporated into the plants and ultimately find their way into the food chain. The presence of radionuclides in varied concentrations in different parts of the plants may be transferred to human beings, since their parts are used as ingredients in preparing the medicines. The estimation of risk to humans from medicinal plants through ingestion requires a quantitative understanding of the interrelated pathways by which the radionuclides are eventually ingested by humans (Eisenbud, 1987). Thus, it is important to study the uptake and activity distribution of radionuclides and the probable effective radiation dose to humans, by the use of medicinal plants.

2. Materials and methods

2.1. Sampling area

The Malnad region (N 13°29′35.4″; E 75°18′02.4″) of Karnataka is a part of the Western Ghats of South India. The eastern parts of Dakshina Kannada and Udupi districts, and parts of Belgaum, Uttara Kannada, Chikkamagalur, Shimoga, Hassan, and Kodagu districts of Karnataka state come under this region. Medicinal plant samples are collected from Chikkamagalur district of this region (Fig. 1). The entire region is agrarian and arecanut, coffee, pepper, tea, rice, ginger, turmeric, vanilla, cardamom, etc. are the important crops grown in this region. The population of this region use Ayurvedic and folklore medical systems extensively in which different parts of the plants are used as main ingredients.

2.2. Sampling

Eight medicinal plants used extensively for treating various diseases were identified for investigation under this study. Different parts of the plants used as ingredients in medicine preparation in this region were collected, following the standard methods given in EML procedure manual (Volchok & De Planque, 1983). Polythene bags washed with distilled water were used to store the plant samples, and then, taken to the laboratory. Soil samples were also collected from the rooting area of the plants. The details of the medicinal plants such as sample number, common and botanical names, curative properties, and parts of the plant used as ingredients in medicine are presented in Table 1.

2.3. Sample preparation

The medicinal plant samples were first air dried, and then, dried at 110 °C in an oven until a constant dry weight was obtained. The samples were charred over a low flame on a gas stove and ashed in a muffle furnace at 450 °C until a uniform white ash was obtained. The ash was stored in a 300 ml polythene container, sealed, and kept for one month to achieve secular equilibrium between ^{226}Ra and its daughters (Volchok & De Planque, 1983). Activity concentrations of ^{226}Ra, ^{210}Pb, ^{232}Th, ^{40}K, and ^{137}Cs were estimated using gamma spectrometric method (Karunakara et al., 2003). Soil samples were also processed following the standard methods given in EML procedure manual (Volchok & De Planque, 1983). Activity concentrations of ^{226}Ra, ^{210}Pb, ^{232}Th, ^{40}K, and ^{137}Cs in soil samples were estimated using gamma spectrometric method (Karunakara et al., 2003).

2.4. Sample analysis

The medicinal plant and soil samples were analysed for activity concentrations of ^{226}Ra, ^{210}Pb, ^{232}Th, ^{40}K, and ^{137}Cs using HPGe gamma spectrometer. A p-type closed end co-axial detector (Model BE3825, Canberra,USA) of dimensions 70 mm diameter and 25 mm length with an active area 3800 mm^2 having 38% relative efficiency was used in the present study. The energy resolution of the detector is 2.2 keV at 1.33 MeV with an operating voltage of 4000 V.The spectrum was analysed using a 16 K multi channel analyser connected to a computer using GENIE-2000 software. Quality assured standard materials procured from IAEA were used for the calibration of the detector. The reference materials used in the case of soil samples were RGU-238, RGTH-232, RGK-1, and Soil-6. IAEA-308 reference standard material was used for calibration and analysis of the ash samples. Same size containers were used for both, the reference standards and the samples under study. The ash samples were counted for 60,000 s and the soil samples for 30,000s. Longer counting time ensures least counting error. The activities of ^{210}Pb, ^{40}K, and ^{137}Cs were measured from their characteristic gamma lines of

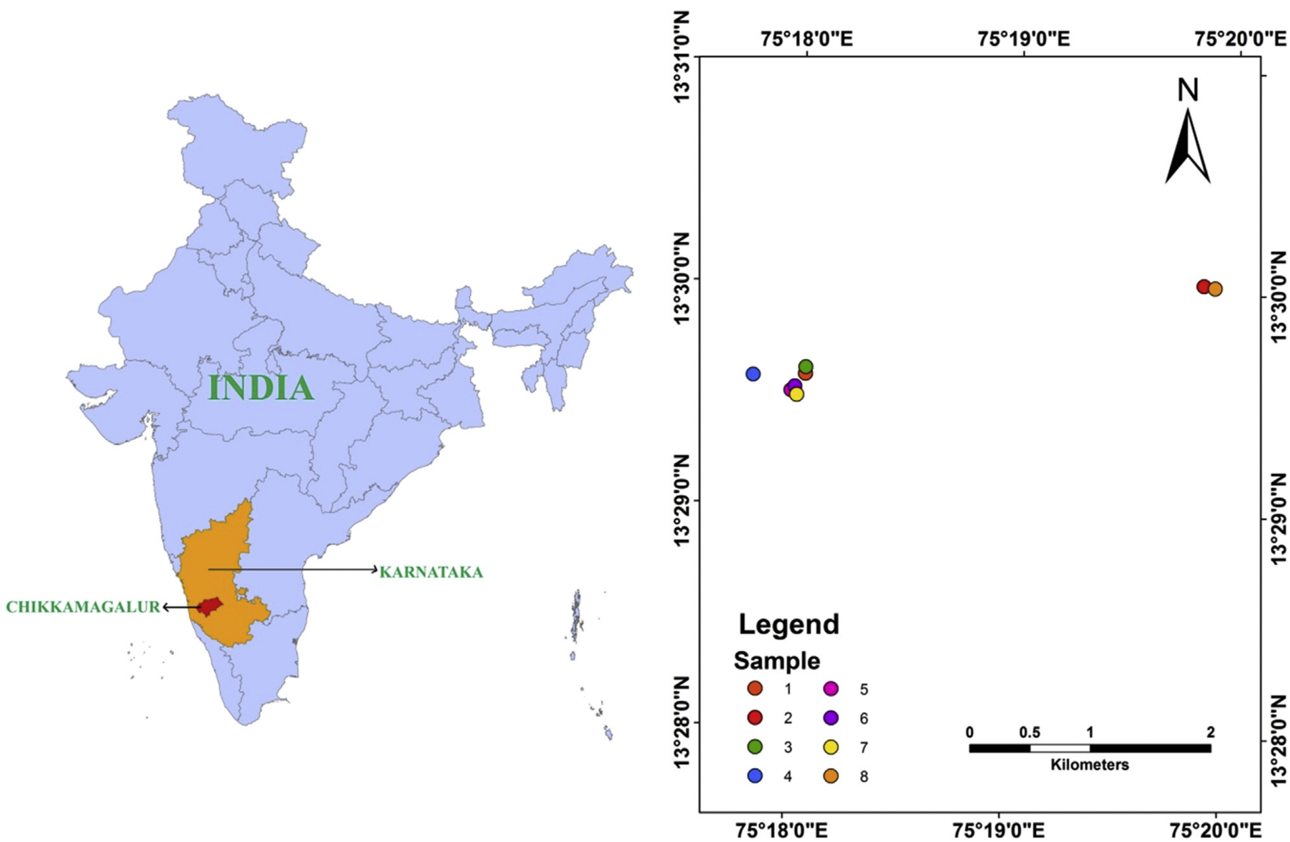

Fig. 1 – Map showing the sampling area.

Table 1 – Curative properties of medicinal plants.

Plant: Sample number & common name	Plant: Botanical name	Curative property	Part used
1.Adusoge	*Justica adhatoda* L.	Bechic, Antiasthmatic, Expectorant, Uterotonic, Chronic bronchitis, Antidiarrhoeal	Leaves
2.Athi	*Ficus racemosa* L.	Astringent,Tonic, Menorrhagia	Bark
3.Devil weed	*Eupatorium odoratum* L.	Skin diseases, Wounds and rashes, Mosquito repellent	Leaves
4.Kottemullu	*Ziziphus rugosa Lam.*	Astringent, Mouth ulcer, Diarrhoea, Menorrhagia	Bark
5.Nimbe	*Cittrus limon* (L.) Burm.	Antiseptic, Antibiotic, Antiviral, Antioxident, General tonic, Cancer preventer, Diuretic, Blood purifier, Skin diseases, Antiinflammatory	Fruit
6.Mandara	*Bauhinia acuminata* L.	Anti cancer drug, Skin diseases, Worms, Diabetes, Gastrointestinal and Respiratory diseases	Bark
7.NachikeMullu	*Mimosa Pudica* L.	Uterine disorders, Wounds, Leprosy, Urinary complaints, Hydrocele, Glandular swellings, Burning sensation, Piles, Fistula, etc.,	Whole plant
8.Nagasampige	*Mesua ferrea* auct Linn.	Tonic, Bechic, Astringent, Sudorific	Bark

energies 46.7, 1460.8, and 661.6 keV, respectively, after applying Compton corrections, corresponding to these radionuclides. The activity of ^{232}Th was inferred from the Compton corrected photo peak of its daughter ^{208}Tl with energy 583.1 keV. The activity of ^{226}Ra was found from the weighted mean activities of three photo peaks of ^{214}Bi (609.3, 1120.3, and 1764.5 keV) and ^{214}Pb (352 keV) after applying the Compton corrections. The minimum detectable level of the activity concentrations using the HPGe spectrometer for ^{226}Ra, ^{210}Pb, ^{232}Th, ^{40}K, and ^{137}Cs were 0.62, 0.77, 2.46, 1.42, and 0.09 $Bqkg^{-1}$, respectively, while concentrations below these figures are reported as below detectable level (BDL). Two representative sample spectra with zooming to highlight the important peaks for soil and ash samples are shown in Figs. 2 and 3.

The soil-to-plant transfer factor (TF) of radionuclides was calculated using the following formula (Karunakara et al., 2003):

$$TF = \frac{Activity\ of\ radionuclide\ in\ plant\ \ (Bqkg^{-1}\ dry\ weight)}{Activity\ of\ radionuclide\ in\ soil\ \ (Bqkg^{-1}\ dry\ weight)}$$

2.5. *Average annual committed effective dose (AACED)*

The Average annual committed effective dose (AACED) due to ingestion of naturally occurring radioactive materials

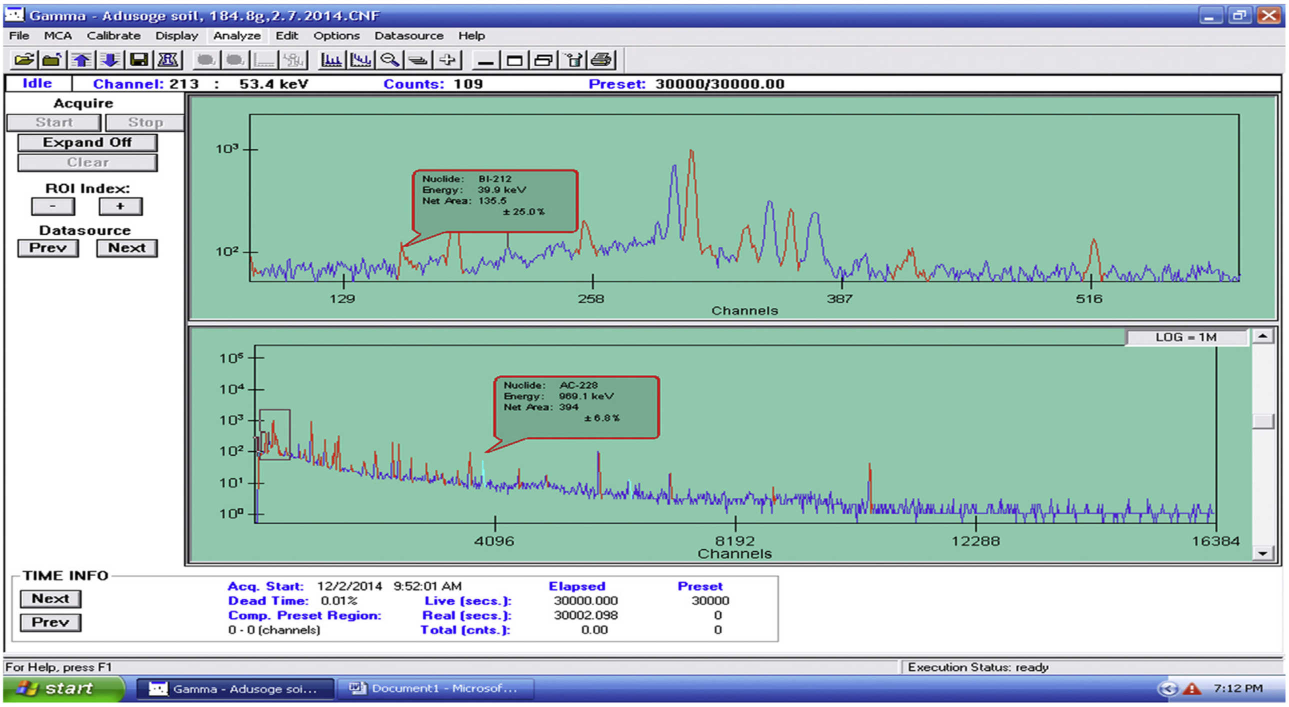

Fig. 2 — Representative spectrum of a soil sample.

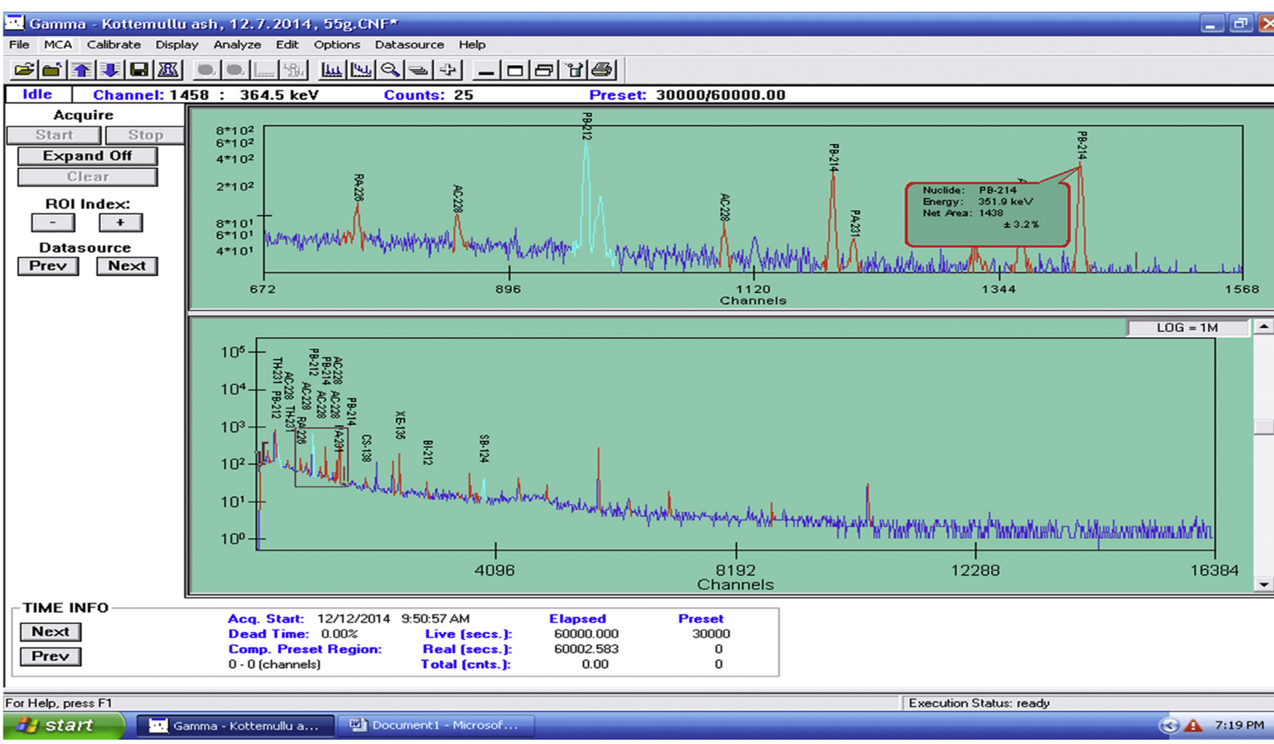

Fig. 3 — Representative spectrum of an ash sample.

(NORMs) in medicinal plants was estimated using the equation (Lordford et al., 2013; Njinga, Jonah, & Gomin, 2015):

$$E_{av} = C_r \cdot DCF_i \cdot A_i \tag{1}$$

where, E_{av} is the average annual committed effective dose, C_r is the consumption rate of radionuclides, and DCF_i is the dose conversion factor for each radionuclide (2.8×10^{-7}, 6.9×10^{-7}, 2.3×10^{-7}, 6.2×10^{-9}, and 1.3×10^{-8} SvBq^{-1} for ^{226}Ra, ^{210}Pb, ^{232}Th, ^{40}K, and ^{137}Cs respectively), and A_i is the activity concentration of each radionuclide. According to equation (1), the committed effective dose to an individual is directly proportional to the consumption rate of the ingredients of medicinal plants as a medicine. Using the same equation, the threshold consumption rate for a medicinal plant can also be obtained from the following relation:

$$C_r = \frac{5E_{av}}{\sum_{i=1}^{5}(DCF_i \cdot A_i)} \tag{2}$$

where, $E_{av} = 0.3$ mSvy^{-1} is the threshold average annual committed effective dose due to ingestion of NORMs in the medicinal plants, A_i is the activity concentration of radionuclide i, and DCF_i is the dose conversion factor for radionuclide i (UNSCEAR, 2000).

3. Results and discussion

The activities of ^{226}Ra, ^{210}Pb, ^{232}Th, ^{40}K, and ^{137}Cs in medicinal plants and in the soil samples collected from the corresponding sampling locations are presented in Table 2. Column 3 of Table 2 suggests that the activity concentrations of ^{226}Ra in the soil of the study area vary from 32.27 ± 1.01 to 60.12 ± 1.62 Bqkg^{-1} with a mean value of 42.16 ± 1.31Bqkg^{-1}. The highest activity of this radionuclide was found in the soil corresponding to the plant *Citrus limon* and the lowest activity was found in the soil corresponding to *Bauhinia accuminata*. In the different parts of the medicinal plant samples under study, the activity concentrations of ^{226}Ra vary from 2.66 ± 0.21 to 11.27 ± 1.59 Bqkg^{-1} with a mean value of 6.34 ± 0.81 Bqkg^{-1}. *Justica adhatoda* and *B. accuminata* contained maximum and minimum activity respectively. It was observed that *J. adhatoda* and *Eupatorium odoratum* have higher activities of ^{226}Ra compared to other medicinal plants, irrespective of the activity of ^{226}Ra in soil. The soil-to-plant transfer factors (TF) of this radionuclide were found to vary from 0.07 to 0.27. The minimum and maximum values of the TF were found respectively in *B. accuminata* and *J. adhatoda*. ^{226}Ra will metabolically in corporate into the plants due to their presence inthe soil in varied concentration (Eisenbud, 1987).

Column 4 of Table 2 presents the activity concentrations of ^{210}Pb in the soil samples, medicinal plants, and TF from soil to medicinal plants. ^{210}Pb was found to vary from 56.09 ± 5.94 to 160.56 ± 7.50 Bqkg^{-1} with a mean value of 89.22 ± 7.33 Bqkg^{-1}in the soil sample. The minimum and maximum values of the activities of ^{210}Pb were found in the soil corresponding to *E. odoratum* and *J. adhatoda* plants, respectively. The activity concentrations of ^{210}Pb in the medicinal plant samples were found in the range of BDL and 87.03 ± 13.33 Bqkg^{-1} with a mean value of 27.29 ± 2.79 Bqkg^{-1}. The minimum and maximum values of the activities of this radionuclide in plant samples were found in *Ficus racemosa* and *J. adhatoda*, respectively. The TF values of ^{210}Pb were in the range of BDL to 0.80. The maximum TF for ^{210}Pb was found in *E. odoratum*. The minimum value (BDL) was found in *F. racemosa* and *C. limon*. The ^{210}Pb present in the soil and in excess as compared to ^{226}Ra may be due to its dry and wet deposition from the atmosphere, in addition, to its presence as decay products of ^{238}U series. As a result, the uptake of these radionuclides and their concentration in plants is higher by orders of magnitude in some cases as compared to ^{226}Ra. In

Table 2 – Activity concentrations and transfer factors of radionuclides.

Plant	Quantity	^{226}Ra	^{210}Pb	^{232}Th	^{40}K	^{137}Cs
Justicaa dhatoda L.	Activity in soil (Bqkg^{-1})	41.30 ± 1.38	160.56 ± 7.50	68.54 ± 2.64	287.00 ± 11.96	7.56 ± 0.71
	Activity in plant (Bqkg^{-1})	11.27 ± 1.59	87.03 ± 13.33	5.07 ± 2.15	6831.40 ± 490.28	BDL
	TF	0.27	0.54	0.07	23.80	BDL
Ficus racemosa L.	Activity in soil (Bqkg^{-1})	32.62 ± 1.26	94.82 ± 9.10	66.92 ± 2.77	712.85 ± 19.52	3.57 ± 0.55
	Activity in plant (Bqkg^{-1})	4.51 ± 0.23	BDL	8.72 ± 0.44	832.95 ± 59.69	BDL
	TF	0.13	BDL	0.13	1.16	BDL
Eupatorium odoratum L.	Activity in soil (Bqkg^{-1})	42.65 ± 1.35	56.09 ± 5.94	72.21 ± 2.70	311.64 ± 12.50	1.23 ± 0.49
	Activity in plant (Bqkg^{-1})	11.15 ± 0.66	45.36 ± 4.59	4.87 ± 0.79	1305.00 ± 94.74	BDL
	TF	0.26	0.80	0.06	4.18	BDL
Ziziphus rugosa Lam.	Activity in soil (Bqkg^{-1})	34.09 ± 1.07	93.24 ± 5.40	49.61 ± 2.00	317.71 ± 15.03	12.34 ± 0.67
	Activity in plant (Bqkg^{-1})	5.98 ± 2.56	7.78 ± 1.20	5.10 ± 0.31	143.99 ± 10.83	BDL
	TF	0.17	0.08	0.10	0.45	BDL
Cittruslimon (L.) Burm.	Activity in soil (Bqkg^{-1})	60.12 ± 1.62	91.88 ± 7.88	98.46 ± 3.33	318.92 ± 13.17	1.05 ± 0.50
	Activity in plant (Bqkg^{-1})	6.08 ± 0.73	BDL	5.67 ± 1.00	1910.00 ± 139.09	BDL
	TF	0.10	BDL	0.05	5.98	BDL
Bauhinia acuminata L.	Activity in soil (Bqkg^{-1})	32.27 ± 1.01	70.13 ± 5.20	51.93 ± 1.89	279.89 ± 13.22	1.54 ± 0.45
	Activity in plant (Bqkg^{-1})	2.66 ± 0.21	47.93 ± 4.27	2.42 ± 0.36	3724.00 ± 27.44	BDL
	TF	0.07	0.68	0.04	13.33	BDL
Mimosa pudica L.	Activity in soil (Bqkg^{-1})	55.53 ± 1.49	73.14 ± 10.03	95.53 ± 3.00	241.57 ± 11.02	BDL
	Activity in plant (Bqkg^{-1})	5.35 ± 0.34	23.06 ± 2.36	4.14 ± 0.44	320.86 ± 2.40	BDL
	TF	0.09	0.31	0.04	1.32	BDL
Mesua ferrea auct L.	Activity in soil (Bqkg^{-1})	38.71 ± 1.31	73.92 ± 7.61	69.54 ± 2.54	536.19 ± 16.21	BDL
	Activity in plant (Bqkg^{-1})	3.73 ± 0.17	7.18 ± 0.88	4.43 ± 0.26	93.79 ± 7.19	BDL
	TF	0.09	0.09	0.06	0.17	BDL

addition to ^{210}Pb uptake by plants through root system from soil; absorption also takes place through leaves. ^{210}Pb being one of the radionuclides depositing on leaves due to dry and wet deposition, may be absorbed subsequently by the leaves. The area of the leaves of *J. adhatoda* is large compared to the leaves of other medicinal plants under present study. This may be the reason for the higher activity of ^{210}Pb in *J. adhatoda* (Karunakara, 1997).

Column 5 of Table 2 reports activity concentrations of ^{232}Th in the soil and medicinal plant samples. The values of TFs are also presented in this column. The activity concentrations in the soil samples vary from 49.61 ± 2.00 to 98.46 ± 3.33 Bqkg^{-1}. The mean value of the activities in soil was 71.59 ± 2.60 Bqkg^{-1}. The maximum activity of ^{232}Th was found in the soil related to *C. limon* and minimum activity was found in that corresponding to *Ziziphus rugosa*. In medicinal plant samples, the minimum and maximum activities were reported for *B. accuminata* and *F. racemosa*, respectively. The activity concentrations in these samples ranged from 2.42 ± 0.36 to 8.72 ± 0.44 Bqkg^{-1} with a mean value of 5.05 ± 0.71 Bqkg^{-1}. In spite of significant variation of activity of ^{232}Th in soil, it was found that there is no significant variation of the activity of this radionuclide in medicinal plants. The TFs of ^{232}Th were found to vary from 0.04 to 0.13.

^{40}K is another primordial radionuclide, whose activity is much significant compared to the other radionuclides. Activity concentrations in the soil, medicinal plants, and TFs are presented in column 6. The ^{40}K concentration in the soil varied between 241.57 ± 11.02 and 712.85 ± 19.52 Bqkg^{-1} with a mean value of 375.72 ± 14.07 Bqkg^{-1}. The maximum activity was found in the soil corresponding to *F. racemosa* and the minimum activity was in that corresponding to *Mimosa pudica*. Its activity concentrations varied from 93.79 ± 7.19 to 6831.40 ± 490.28 Bqkg^{-1}, in medicinal plant samples with a mean value of 1895.24 ± 103.95 Bqkg^{-1}. The highest and lowest activities in medicinal plant samples were found in *J. adhatoda* and *Mesua ferrea* respectively. The TF values were found to vary between 0.17 and 23.80. *J. adhatoda* plant has the maximum TF, where as *M. ferrea* exhibits the minimum value. The comparison of activity concentrations among the soil and medicinal plant samples and their corresponding TFs are presented in Figs. 4–6. It is evident from Fig. 4 that the activity concentration of ^{40}K is maximum in the soil compared to other radionuclides reported in this study. The activity concentration of artificially produced radionuclide ^{137}Cs is the least, compared to all other radionuclides. However, it is above the minimum detectable level in all the samples, except for *Bauhinia acuminata* and *M. ferrea*. The activity of ^{226}Ra is lower than the activities of ^{210}Pb and ^{232}Th in all the soil samples. The activity concentrations of ^{210}Pb and ^{232}Th in soil are almost equal except to that corresponding to *Justica adhathoda*. It can be observed from Fig. 5 that the concentration of ^{40}K is significantly large compared to any other radionuclide, in all the medicinal plants.^{40}K being an isotope of potassium, which is an important nutrient of the plants in their metabolic activities, and is available in abundance in the soil is expected to be more, compared to other radionuclides. The continuous uptake and accumulation of this radionuclide over a period may be one of the reasons of its higher concentration in plants. Plant metabolism is another factor that decides the uptake and activity concentration of ^{40}K (ChethanRao, 2012) in medicinal plants. Even though there is no significant variation in soil, some medicinal plants have higher activity concentration of ^{40}K compared to others. This may be due to the property of these medicinal plants to absorb potassium channels more, required for their metabolic activities, compared to other medicinal plants. It is observed that the *J. adhathoda* plant has maximum concentration of ^{40}K. A number of potassium channels are involved in the treatment of health problems related to the respiratory system such as asthma, cough, and chronic obstructive pulmonary diseases (Malerba, Radaeli, Mancuso, & Polosa, 2010). *J. adhathoda* has the medicinal property to cure diseases related to the respiratory system as given in Table 1. May be because of this medicinal property, *J. adhathoda* contain higher activity concentration of ^{40}K. The medicinal property (remedy in respiratory diseases) of *B. accuminata* may also be the reason for its significant activity concentration (3724.00 ± 27.44Bqkg^{-1}) of ^{40}K. Further, it can be seen that though the activity concentration of ^{40}K in the soil corresponding to *F. racemosa* and *M. ferrea* are large compared to other soil, its concentration in these plants is found to be low. This suggests selective and preferential uptake of ^{40}K by these plants.

The activity concentrations in the soil, medicinal plants, and TF values of ^{137}Cs are presented in the last column of the table. Its activity concentrations in the soil vary from BDL to 12.34 ± 0.67 Bqkg^{-1} with a mean value of 3.41 ± 0.42 Bqkg^{-1}. The soil sample collected corresponding to the *Ziziphus rugosa* plant showed maximum activity concentration and its concentration in all the medicinal plant samples were found to be in the BDL level. It has been reported by several investigators that ^{137}Cs is tightly bound to the clay minerals of the soil, and therefore, the root uptake is insignificant (Eisenbud, 1987).

Even though the activities of ^{210}Pb and ^{232}Th are almost in equal concentration in the soil samples, the uptake and measured activity concentration of ^{210}Pb is more compared to that of ^{232}Th in most of the plants. In addition to the root uptake, ^{210}Pb is available to the plant parts in the form of wet and dry precipitate in the atmosphere. The deposition of ^{210}Pb in this form will proportionately increase with the age of leaves (Parfenov, 1974). It is also known that substances present in the soil, contaminate plants by means of rain splash in which minute particles of substances impact with raindrops and deposit on plant parts to a height of about 40 cm (Dreicer, Hakonson, White, & Whicker, 1984). *J. adhathoda, B. accuminata* and *E. odoratum* are naturally grow to smaller heights, and may be, for the reason these plants show higher concentration of ^{210}Pb. Fig. 6 presents the variation of TF of radionuclides from soil to medicinal plants. As expected, ^{40}K exhibited maximum TF in almost all the medicinal plants under study followed by ^{210}Pb. ^{137}Cs recorded least TF, which may be due to its very low concentration in the soil samples. Among ^{226}Ra and ^{232}Th, the TF of ^{226}Ra is relatively higher, and it may be due to the fact that radium is chemically similar to calcium, and calcium being one of the nutrients, plants may absorb radium with calcium, which will result in relatively more concentration of radium, and hence, the transfer factor. This is because the radioisotopes of elements that are ordinarily present in the soil and that are utilised in plant metabolism are absorbed in a manner independent of the radioactive

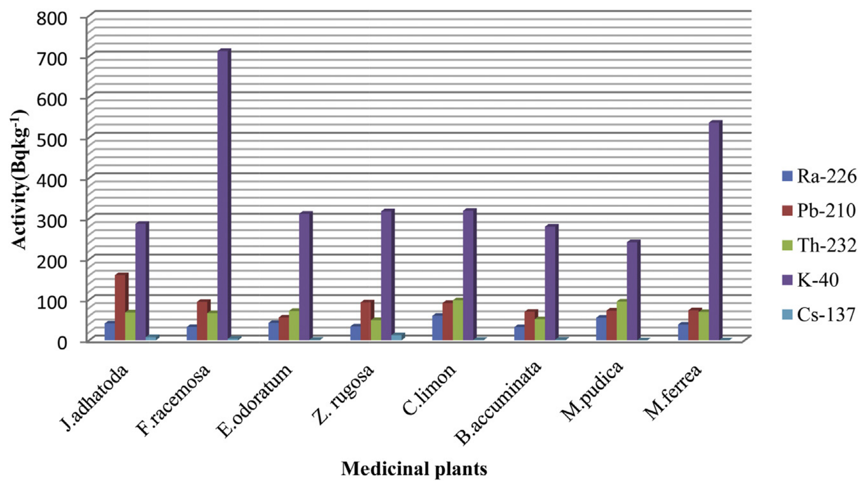

Fig. 4 – Activity of radionuclides in the soil samples.

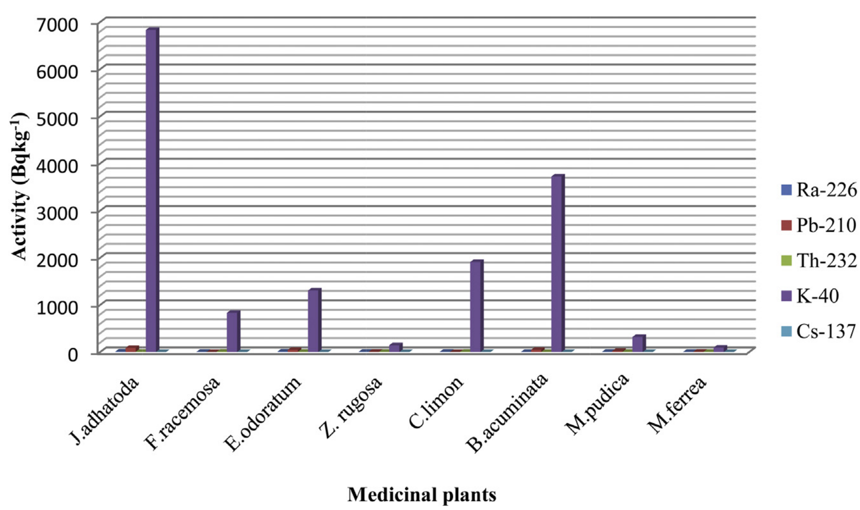

Fig. 5 – Activity of radionuclides in medicinal plant samples.

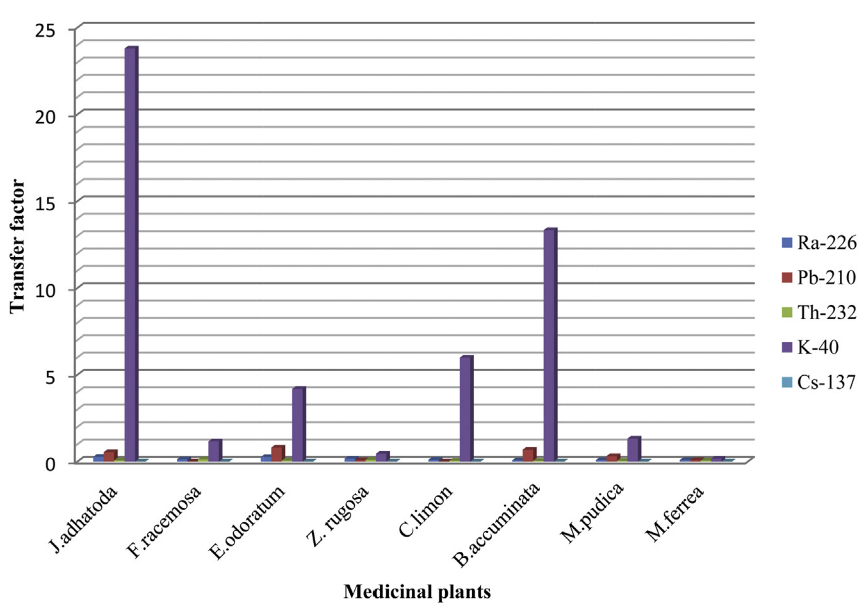

Fig. 6 – Soil to plant transfer factors (TF) of radionuclides.

Table 3 – Background radiation, AACED, and threshold consumption rates of medicinal plants.

Medicinal plant	Location	Gamma background radiation level ($nSvh^{-1}$)	AACED ($mSvy^{-1}$)	Threshold consumption rate (kgy^{-1})
Justica adhatoda	N 13°29′35.4″ E 75°18′02.4″	100	0.1067 ± 0.0136	2.81
Ficus racemosa	N 13°30′2.4″ E5°19′51.9″	130	0.0084 ± 0.0005	35.71
Eupatorium odoratum	N 13°29′37.2″ E 75°18′2.5″	110	0.0436 ± 0.0041	6.88
Ziziphus rugosa	N 13°29′34.7″ E75°17′48.0″	110	0.0091 ± 0.0016	32.96
Cittrus limon	N 13°29′30.8″ E 75°17′58.6″	100	0.0148 ± 0.0012	20.27
Bauhinia acuminata	N 13°29′31.9″ E 75°17′59.9″	110	0.0580 ± 0.0032	5.17
Mimosa pudica	N 13°29′29.7″ E 75°18′0.2″	120	0.0235 ± 0.0019	12.76
Mesua ferrea	N 13°30′1.9″ E 75°19′55″	130	0.0075 ± 0.0007	40

properties. May be the ^{232}Th content in medicinal plants is less because of its insolubility and low specific activity. The ions of this element may bound so tightly to the soil particles that they remain immobile and are not absorbed by the plants (Eisenbud, 1987).

The fallout of artificial radionuclides such as ^{137}Cs may occur in a region due to tropical climate with high precipitation and evergreen forest. The evergreen forest may increase the clay content and organic matter in the soil. As a result, the retention capacity of the radionuclides in the soil increases (Eisenbud, 1987). The region under the present study also has a tropical climate with high precipitation and comes within an evergreen forest. This may be the reason for the observed activity concentration of ^{137}Cs in the soil samples in trace quantity.

Table 3 presents gamma background radiation level, AACED, and the threshold consumption rate of the corresponding medicinal plants along with their details of location. It can be seen from the Table 3 that the gamma background radiation level ranges between 100 and 130 $nSvh^{-1}$ due to the radionuclides present in the environment. Assuming a consumption rate of 1 kgy^{-1} (Njinga et al., 2015), the AACED values due to the ingestion of ^{226}Ra, ^{210}Pb, ^{232}Th, ^{40}K, and ^{137}Cs for the medicinal plants were estimated and are presented in column 4, and it varies from 0.0075 ± 0.0007 to 0.1067 ± 0.0136 $mSvy^{-1}$ with a mean value of 0.03395 ± 0.00335 $mSvy^{-1}$. The maximum value of AACED was obtained for *J. adhatoda* and the minimum for the *M. ferrea* plant. The variations of AACED values in different medicinal plants are also presented in Fig. 7. The AACED value is maximum for *J. adhatoda* because of the higher concentration of ^{40}K and relatively more concentration of ^{210}Pb, while these are minimum in *B. accuminata*, which accounts for the lower value of AACED in the plant. Depending on the activity

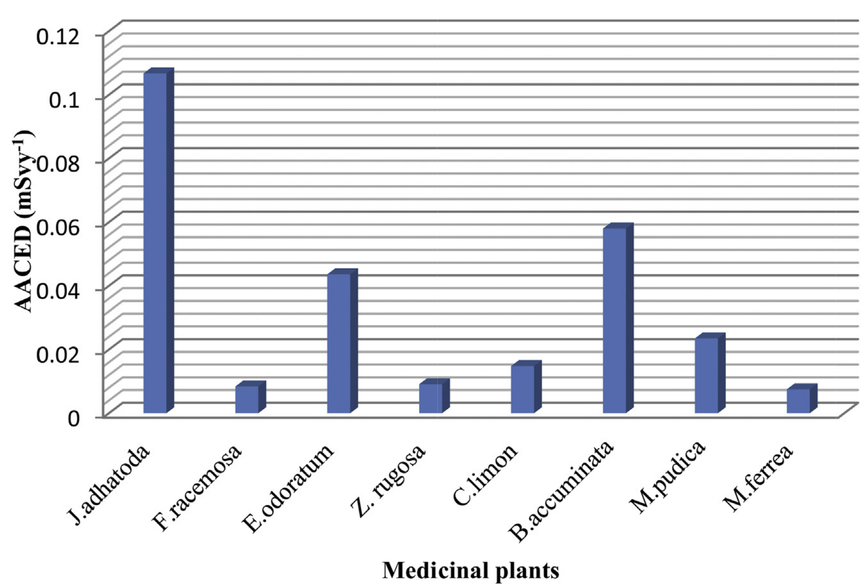

Fig. 7 – AACED due to medicinal plants.

Table 4 – Comparison of TF with the literature values.

Radionuclide	Plants	T.F.	Reference
^{226}Ra	Plants under this work	0.07–0.27	Present study
	35 different plants	0.19–0.73	Harb et al., 2014
	Ipomoea batatas	0.50–0.74	Asaduzzaman, Khandekar, Amin, Bradley, Mahat, & Nor, 2014
	Ficus religiosa	0.36	Karunakara et al., 2003
	Clerodendrum viscosum	0.17	Karunakara et al., 2003
^{210}Pb	Plants under this work	BDL – 0.80	Present study
	Leaves of vegetable	0.37–1.4	Al-Masri et al., 2008
	Rice plant (Root)	0.17–0.92	ChethanRao, 2012
	Fruit vegetable	0.01–0.34	ChethanRao, 2012
^{232}Th	Plants under this work	0.04 to 0.13	Present study
	6 different plants	BDL-0.341	Manigandan & Chandrashekar, 2014
	35 different plants	0.09–0.88	Harb et al., 2014
	Saliva nemorsa	0.11	Pourimani, Noori, & Madadi, 2015
^{40}K	Plants under this work	0.17 – 23.80	Present study
	6 different plants	0.128–0.954	Manigandan & Chandrashekar, 2014
	Careya arboreaRoxb.	1.14–1.96	Karunakara N., 1997
	Rice plant root	0.4- 8.8	ChethanRao, 2012
	Ficus religiosa	3.73	Karunakara et al., 2003
	Clerodendrum viscosum	2.27	Karunakara et al., 2003
^{137}Cs	Plants under this work	BDL	Present study
	Grass	0.03 – 0.44	Ujwal Prabhu, 2012
	Spinach	0.2	ChethanRao, 2012
	Medicago sativa	0.08	Pourimani et al., 2015

concentrations of radionuclides, similar types of variation in AACED was observed for all other plants. The AACED values reported in this study are far below the world average value of 0.3 $mSvy^{-1}$ (UNSCEAR, 2000). The estimated threshold consumption rates of medicinal plants are presented in last column of the table. A plant with higher AACED value would have lower threshold consumption rate and vice versa. The highest threshold consumption rate was obtained for *Mesuaferrea* (40 kgy^{-1}) and the lowest for *J. adhatoda* (2.81 kgy^{-1}). The comparison of TFs of radionuclides in the medicinal plants under the present study with the literature values is presented in Table 4.

4. Conclusion

This study found that the uptake and activity concentration of ^{40}K was significantly large compared to any other radionuclide in all the medicinal plants. The important observation of this study is that the activity concentration of radionuclides in medicinal plants mainly depends on the type of plants and not on the activity of these radionuclides in soil. Since Potassium, channels are involved in the treatment of health problems related to the respiratory system such as asthma, cough, and chronic obstructive pulmonary diseases, higher concentrations of ^{40}K in *J. adhatoda* and *B. accuminata* support their medicinal use in the treatment of the above said ailments. The AACED due to the ingestion of radionuclides, reported in this study are far below the world average of 0.3 $mSvy^{-1}$. Thus, the study suggests that there is no radiological health risk in using these medicinal plants to treat the diseases. This may help the public to come out of the indecisive state of using these medicinal plants, especially in the present condition of global adulteration. The study may also help in forming a framework of environmental safety regulations related to radiological healthcare.

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